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DOCUMENTATION REPORT
GROUND WATER RECOVERY OPERATIONS

STANDARD CHLORINE OF DELAWARE, INC.
DELAWARE CITY, DELAWARE

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WESTON

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INTRODUCTION

In response to the 22 January 1988 Consent Order between the Delaware Department of Natural Resources and Environmental Control (DNREC) and Standard Chlorine of Delaware, Inc., this report has been prepared to present an analysis of documentation from the ground-water pumping and contaminant recovery conducted prior to the Order. This report also contains an evaluation of the effectiveness of the recovery system, and recommended modification to the current system.

In addition, the report includes a summary of water level and analytical data, pumping history and withdrawal rates from the recovery well system. Documentation presented in this report covers the period from the initiation of the recovery well pumping in June 1986 to March 1988.

BACKGROUND

Hydrogeologic investigations were conducted at the Standard Chlorine Chemical Company facility in Delaware City, Delaware, to ascertain the magnitude and extent of contamination resulting from the spill of 5000 gallons of monochlorobenzene (MCB) in September 1986. Other benzene and polychlorinated benzenes were also found in the ground water within the shallow, Columbia aquifer at the facility. A site map showing the location of monitor wells installed during the site investigation is shown in Figure 1. The contamination plume, as defined by contouring total benzenes, was found to extend beyond the northern plant boundaries of the plant onto land owned by Diamond Shamrock.

During earlier parts of the investigation it became obvious that excavation of contaminated soils was not a feasible component of the remediation of the problem, and that the feasibility of pumping and treating ground water should be investigated. A 37 gpm, 73-hour pump test was conducted on monitor well TW-6A (see Figure 1), at a very early stage of the project. The results of that test indicated that pumping and treating ground water at the facility was a feasible concept. That concept was presented to the State Department of Natural Resources and Environmental Control (DNREC) and was approved.

To intercept and recover the ground-water contaminants, four ground-water pumping wells (RW-1 through RW-4) were installed north of the Standard Chlorine facility at the downgradient end of the contaminant plume. Figure 1 shows the location of recovery wells RW-1 through RW-4. The recovery wells range in depth between 63 and 69 feet below ground surface. Recovery wells RW-1 through RW-4 were put into service in mid-June 1986 upon completion of construction of the new air stripper treatment system and treatment of the supernatant from the sedimentation basins built in relation to the 1986 spill cleanup.

MONITORING ACTIVITIES

Subsequent to the startup of the recovery system in mid-June 1986, monitoring activities for the recovery well system (RW-1 through RW-4) included the following:

- Water level measurements
- Pumping rate and operational conditions (ie. pump on/off).
- Ground-water sampling and analysis.

The history of pumping and the average monthly withdrawal rates at recovery wells RW-1 through RW-4 are presented in Tables 1 and 2, respectively. The average monthly withdrawal rates was calculated using only the days that pumping occurred in the month. Water level data from the recovery wells is summarized in Table 3. A summary of the analytical data (Table 4) compiles the information for each well on the number of samples collected and the average total organic concentrations for each month. A discussion of the aforementioned information is included in the following section.

EVALUATION OF THE RECOVERY SYSTEM

The pumping of the four recovery wells (RW-1 through RW-4) was initiated in mid-June 1986. The history of pumping for the four recovery wells is presented in Table 1. From the latter part of 1986 to the beginning of 1987, the recovery system encountered several operational problems such as low yields, mechanical problems, well cloggings, etc. During this period, well rehabilitation was conducted to maintain and improve pumping rates, and other operational problems were rectified. For the period of June 1987 to March 1988, the recovery wells (except RW-2) have pumped continuously.

Recovery well RW-2 was brought back on-line in the latter part of 1987 and has pumped continuously from December 1987 to March 1988.

The average monthly withdrawal rates from the recovery wells is given in Table 2. During the initial pumping period it was observed that the wells would sustain pumping rates of 5 to 10 gpm, rather than the assumed rates of 40 gpm. The reduction in pumping rates is due to apparent gradational increases in the percentage of finer grained materials, with a resulting decline in the local transmissivity of the Columbia aquifer near the recovery wells. One benefit to this shift in local transmissivity is that lower pumping rates can apply the same stresses to the aquifer as the higher rates would in a more transmissive area of the aquifer. An added benefit of this finding is that there now exists excess treating capacity, and additional recovery wells could be brought on-line to accelerate the rate of ground water cleanup.

The overall intent of the ground water recovery system was to create a hydrodynamic control at the downgradient end of the contamination plume, and to recover contaminated ground water. An evaluation of the recovery system performance conducted during early 1987 (see letter report in Attachment 1) confirmed that this is the case. The evaluation verified that the existing recovery system, at the reduced pumping rate, has been performing to met the remedial program objectives. The test results also indicated that even at a reduced pumping rate, intercepting cones of drawdown can be achieved from the recovery wells.

In December 1987, water level data recorded at the recovery and monitoring wells was used to construct a water level contour map presented in Figure 2. A complete summary of the monthly water level data is presented in Table 3. This map represents actual water levels observed while recovery wells RW-1, RW-3, and RW-4 were pumping. RW-2 was out of commission at the time of water level measurements. Based on the water level contour map, it can be seen that the ground water recovery system is providing an adequate hydrogeologic barrier at the downgradient end of the contamination plume. The pumping rate of the recovery wells was approximately 5 gpm per well. However, even with the low pumping rates, the recovery system is achieving its design purpose.

Based on the October 1987 round of ground water sampling at the site, an isoconcentration map of total benzene was

constructed and is presented in Figure 3. From this figure it can be seen that there are two areas of high concentration within the plume. One is in the proximity of Well TW-6A, and the other is in the northern part of the site. By comparing Figure 3 with the isoconcentration map of 1983 (Figure 4), it can be concluded that total contaminant concentrations in the ground water have decreased. Furthermore, it can be seen that the plume is moving downgradient toward the recovery wells and is getting smaller in size.

Average monthly concentrations of organics recovered at RW-1 through RW-4 is presented in Table 4. This data shows that total organic concentrations at the beginning of pumping (June 1986) ranged between approximately 51 ppm at RW-4 to 460 ppm at RW-2. Overall the analytical data indicates that contaminant concentrations at RW-4 have remained relatively constant throughout the recovery operation. In the same period, the concentrations of total organics at RW-1, RW-2 and RW-3 have declined from the initial concentrations recorded in June 1986. Total organic concentrations in March 1988 show a range of 83 ppm at RW-4 to 276 ppm at RW-2.

RECOMMENDATIONS

In order to increase the rate of contaminated ground water extraction, the following recommendations are made:

1. Install a submersible pump in Well TW-6A and pump the extracted water to the air stripper. This well is located in the highest concentration part of the plume within Standard Chlorine property and will accelerate the recovery of contaminated ground water. It will also ensure that the plume will not leave the western boundary of the site, where aquifer permeability is relatively high. It is more efficient to extract the high-concentration ground water in the south-western part of the site than to allow the plume to migrate northward toward the recovery wells and in the process get diluted thereby increasing its volume and the time that it takes to decontaminate the aquifer.

2. Following the incorporation of TW-6A into the recovery system, an evaluation will be made of the impact of this new pumping well on ground water levels and contaminant recovery. Based on this evaluation, the need for additional recovery wells

to control the seepage of contaminated ground water into the unnamed tributary will be assessed.

3. In order to maintain and possibly increase the pumping rates of the existing recovery wells, they should be rehabilitated through mechanical surging and brushing. This may have to be done periodically to unclog well screens.

4. The analysis of documentation from the ground water recovery system shows that the recovery well can perform their designated function of intercepting and recovering contaminated ground water. The monitoring activities herein also shows that the entire recovery system has been operating continuously from December 1987 and that operational problems associated with the startup have been rectified. Therefore it is proposed that the quarterly monitoring activities required in the Consent order can be reported on an annual basis to the DNREC.

Table 1: HISTORY OF RECOVERY PUMPING WELLS
STANDARD CHLORINE OF DELAWARE, INC.

RW1		RW2	
Pump On	Pump Off	Pump On	Pump Off
06/19/86 - 10/22/86	10/23/86 - 12/27/86	06/18/86 - 10/22/86	10/23/86 - 03/07/87
12/28/86 - 01/04/87	01/05/87	03/08/87 - 04/07/87	04/08/87 - 04/09/87
01/06/87 - 02/25/87	02/26/87 - 02/27/87	04/10/87 - 04/13/87	04/14/87
02/27/87 - 03/03/87	03/04/87	04/15/87 - 05/28/87	05/29/87 - 10/16/87
03/05/87 - 04/07/87	04/08/87 - 04/09/87	10/17/87	10/18/87 - 11/26/87
04/10/87 - 04/13/87	04/14/87	11/27/87 - 3/31/88	
04/15/87 - 05/19/87	5/20/87		
05/21/87 - 07/30/87	07/31/87 - 08/17/87		
08/18/87 - 09/20/87	09/21/87 - 09/22/87		
09/23/87 - 10/12/87	10/13/87 - 10/15/87		
10/16/87 - 11/04/87	11/05/87		
11/06/87 - 3/31/88			

Table 1: HISTORY OF RECOVERY PUMPING WELLS
STANDARD CHLORINE OF DELAWARE, INC.
(Continued)

RW3		RW4	
Pump On	Pump Off	Pump On	Pump Off
06/18/86 - 08/19/86	08/20/86 - 10/20/86	06/20/86 - 10/22/86	10/23/86 - 06/02/87
10/21/86	10/22/86 - 05/27/87	06/03/87 - 07/30/87	07/31/87 - 08/17/87
05/28/87 - 07/30/87	07/31/87 - 08/17/87	08/18/87 - 09/20/87	09/21/87 - 09/22/87
08/18/87 - 09/20/87	09/21/87 - 09/22/87	09/23/87 - 10/12/87	10/13/87 - 10/15/87
09/23/87 - 10/12/87	10/13/87 - 10/15/87	10/16/87 - 11/04/87	11/05/87
10/16/87 - 11/04/87	11/05/87	11/06/87 - 03/31/88	
11/06/87 - 03/31/88			

TABLE 2: AVERAGE MONTHLY WITHDRAWAL RATES (GPM)/
NUMBER OF DAYS PUMPING IN THE MONTH
GROUNDWATER RECOVERY WELLS
STANDARD CHLORINE OF DELAWARE, INC.

MONTH	RW1	RW2	RW3	RW4
1986				
June	*	*	*	*
July	*	*	*	*
August	*	*	* PD	*
September	*	*	Pump Down	*
October	Pump Down	Pump Down	Pump Down	*PD
November	Pump Down	Pump Down	Pump Down	Pump Down
December	Pump Down	Pump Down	Pump Down	Pump Down
1987				
January	*	Pump Down	Pump Down	Pump Down
February	8.7/14	Pump Down	Pump Down	Pump Down
March	6.7/25	4/0/8 *	Pump Down	Pump Down
April	6.6/27	3.2/27	Pump Down	Pump Down
May	6.3/31	2.2/26	6.0/4 PD	Pump Down
June	6.1/30	Pump Down	5.5/30	9.1/29
July	5.3/30	Pump Down	5.2/30	8.7/30
August	5.3/14 PD	Pump Down	5.6/16 PD	8.2/16 PD
September	5.0/28	Pump Down	5.0/28	7.6/28
October	5.9/28	2.1/1 PD	5.3/29	7.7/28
November	6.3/29	2.1/5 PD	5.6/29	8.4/29
December	5.9/31	1.0/31	5.1/31	9.3/31
1988				
January	6.4/31	1.1/31	5.2/31	8.6/31
February	6.0/31	0.9/31	4.2/31	8.4/31
March	6.0/31	0.1/31	3.9/16 *	5.9/31

* Flow Meter Inoperable

PD Pump Down a Portion of the Month

TABLE 3: SUMMARY OF MONTHLY WATER LEVEL DATA
GROUND WATER RECOVERY WELLS
STANDARD CHLORINE OF DELAWARE, INC.

MONTH	RW1	RW2	RW3	RW4
	DEPTH TO WATER (FEET)			
1986				
June 26	52.42	56.67	53.33	49.75
July 3	52.42	49.00	59.00	57.75
August 7	54.42	58.58	58.92	50.83
September 4	51.75	57.75	35.75	53.17
October 2	55.75	60.92	36.83	55.67
November 5	46.33	44.75	36.12	41.58
December 4	46.83	44.50	36.83	38.92
1987				
January 7	58.83	44.17	36.50	38.17
February 5	56.00	No data	36.33	No Data
March 12	50.83	61.00	36.50	38.25
April 1	50.75	63.83	36.92	38.50
May 1	50.75	64.08	36.33	38.33
June 1	50.08	44.50	39.00	38.25
July 1	49.92	44.83	39.17	42.00
August 18	49.25	44.83	39.75	42.25
September 1	49.58	45.00	39.58	42.42
October 1	50.33	45.08	39.92	40.17
November 1	49.67	42.25	39.67	42.25
December 1	49.83	64.08	40.00	42.75
1988				
January 1	50.50	63.83	40.08	42.83
February 1	50.83	64.08	39.67	42.92
March 2	50.33	64.08	39.25	42.50

TABLE 4: NUMBER OF SAMPLES COLLECTED PER MONTH/
AVERAGE MONTHLY CONCENTRATION OF ORGANICS (PPM)
GROUND WATER RECOVERY WELLS
STANDARD CHLORINE OF DELAWARE, INC.

	RW-1	RW-2	RW-3	RW-4
1986				
June	9/251.5	10/460.3	10/175.7	10/50.8
July	12/199.5	12/373.2	12/138.1	11/42.9
August	26/159.4	26/254.7	18/109.8	26/40.3
September	30/150.5	30/287.6	None	30/37.7
October	22/142.1	20/241.1	1/126.3	21/36.5
November	None	None	None	None
December	2/134.2	None	None	None
1987				
January	23/134.6	None	None	None
February	21/106.2	None	None	None
March	30/108.7	24/215.5	None	None
April	27/111.9	27/209.4	None	None
May	30/113.4	21/214.8	4/79.4	None
June	30/95.2	None	30/68.5	28/46.3
July	31/116.2	None	30/94.8	30/60.2
August	14/109.2	None	15/121.6	13/72.4
September	26/90.9	None	26/86.5	26/64.7
October	27/94.6	1/138.9	26/81.8	26/61.9
November	28/55.3	4/174.2	28/76.6	28/45.7
December	28/78.2	28/202.0	26/111.6	28/67.8
1988				
January	29/70.8	28/207.8	29/111.3	29/57.8
February	19/63.2	19/215.7	19/107.9	19/58.5
March	13/86.4	13/276.2	14/145.8	13/83.0

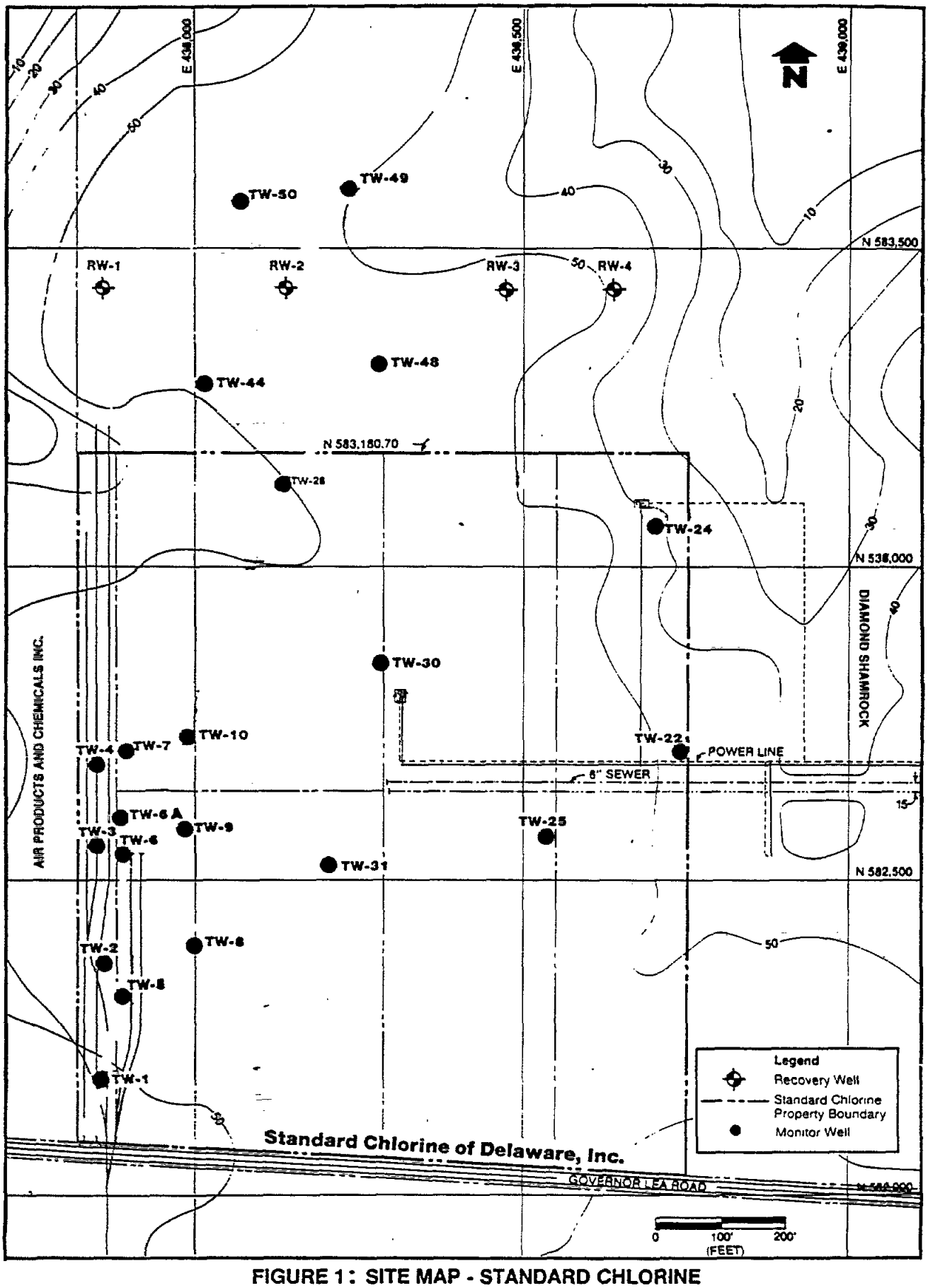

FIGURE 1: SITE MAP - STANDARD CHLORINE OF DELAWARE, INC.

AR307708

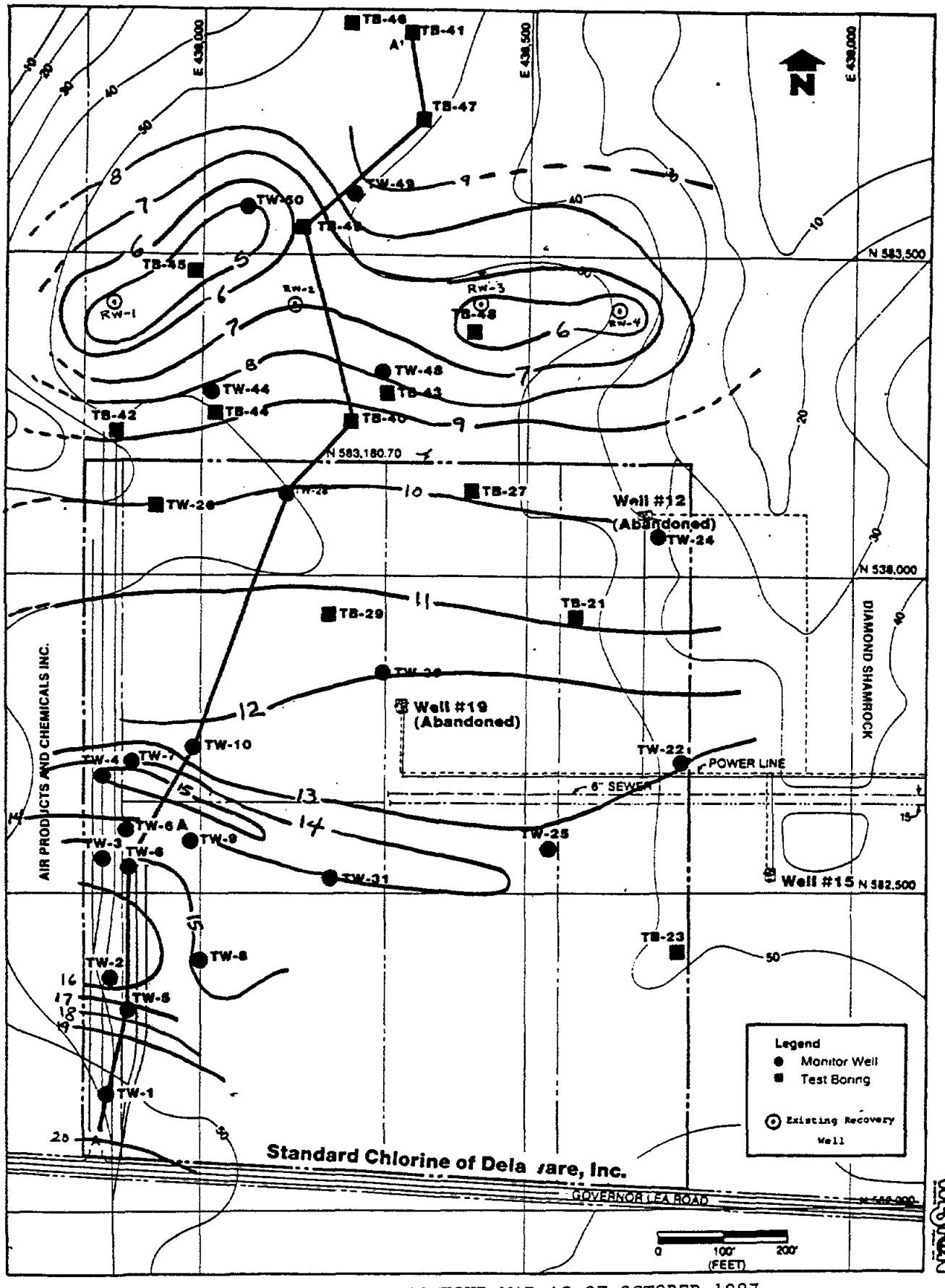

FIGURE 2: WATER LEVEL CONTOUR MAP AS OF OCTOBER 1987
STANDARD CHLORINE OF DELAWARE, INC.
DELAWARE CITY, DELAWARE

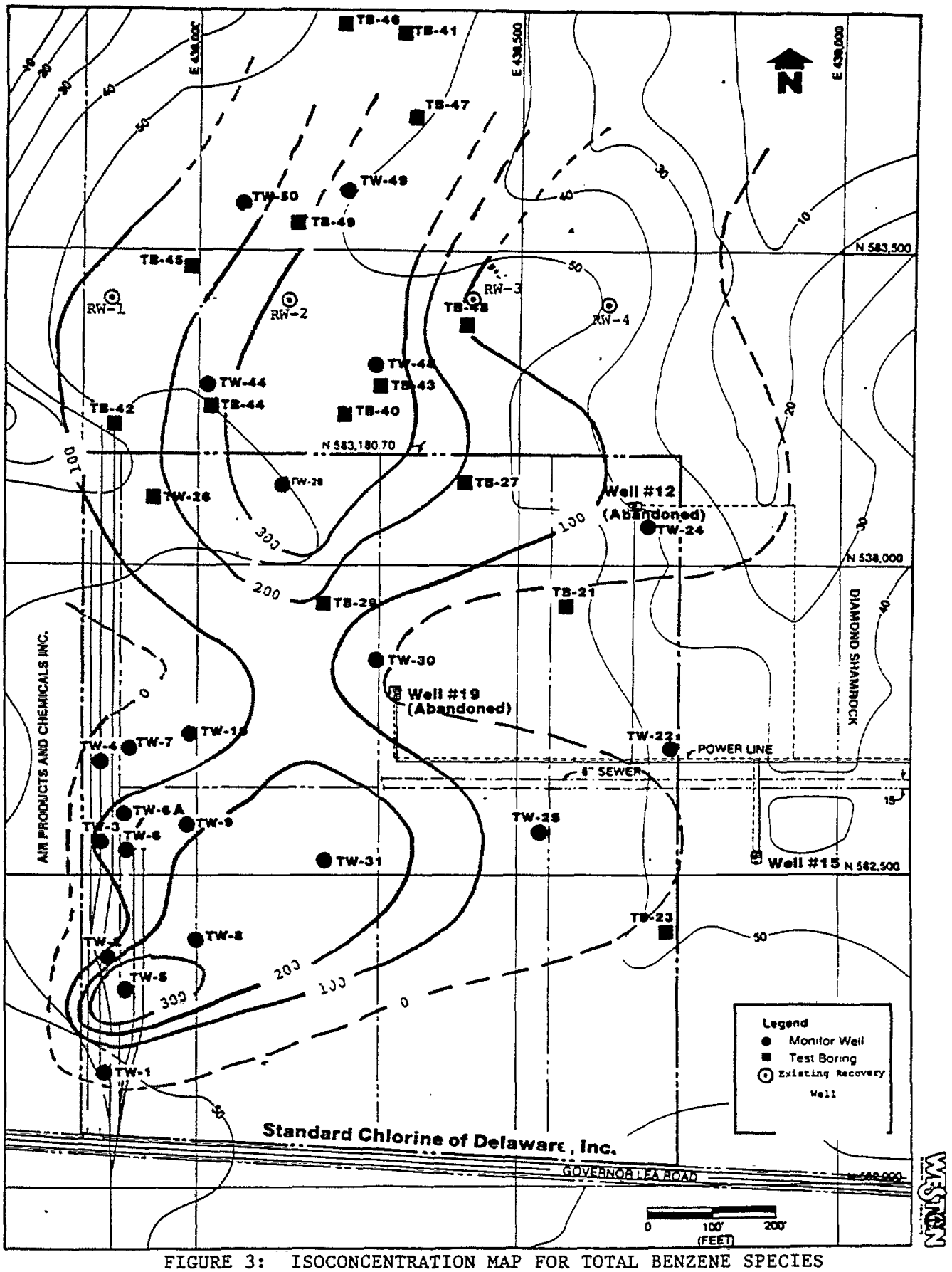

FIGURE 3: ISOCONCENTRATION MAP FOR TOTAL BENZENE SPECIES
AS OF OCTOBER 1987
STANDARD CHLORINE OF DELAWARE, INC.
DELAWARE CITY, DELAWARE

AR307710

~100~ ISOCONCENTRATION OF TOTAL BENZENE (PPM)

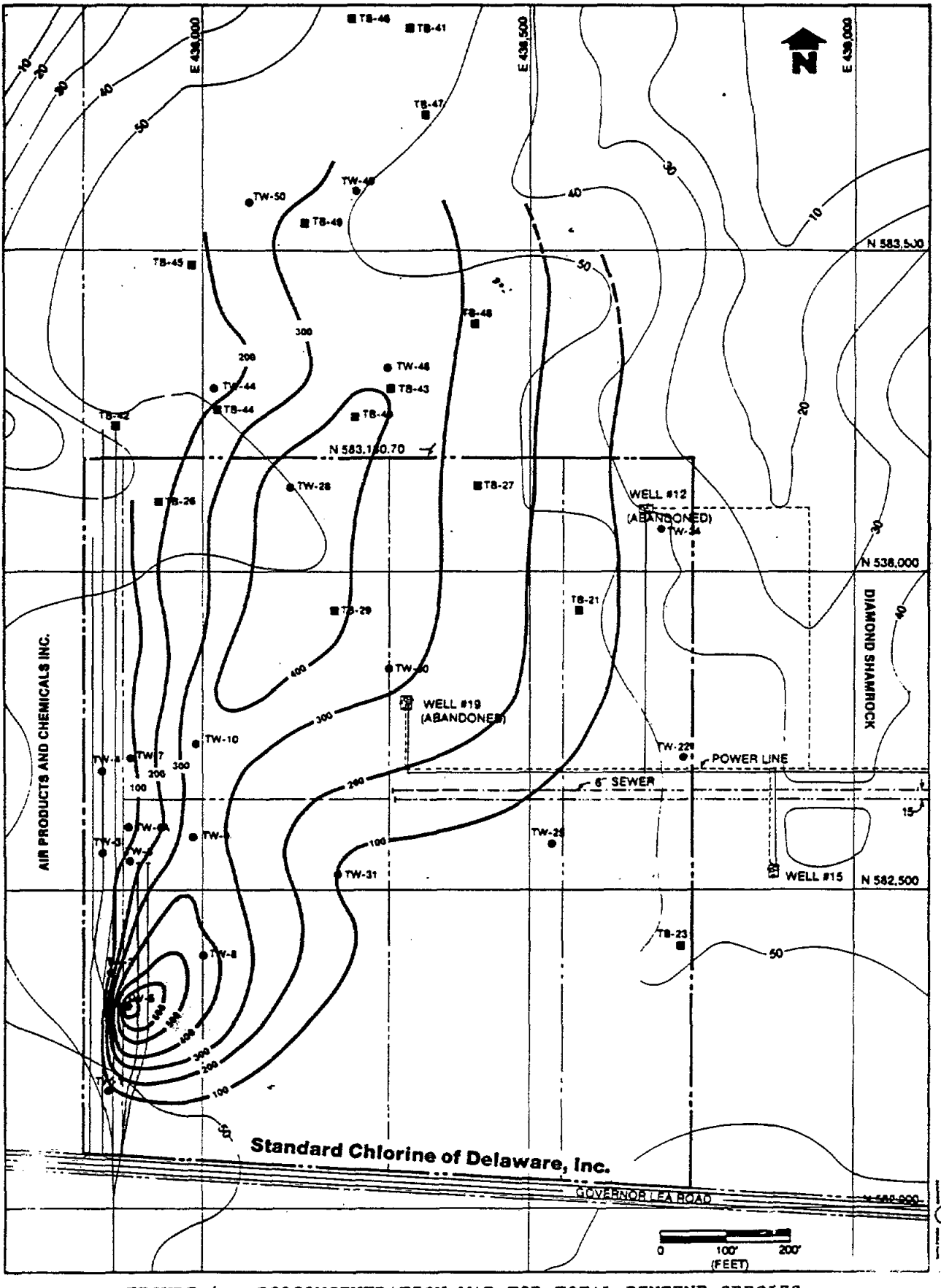

FIGURE 4: ISOCONCENTRATION MAP FOR TOTAL BENZENE SPECIES
AS OF OCTOBER 1983
STANDARD CHLORINE OF DELAWARE, INC.
DELAWARE CITY, DELAWARE

AR307711

ATTACHMENT 1

LETTER REPORT
7 JANUARY 1987

WESTON
DESIGNERS CONSULTANTS
WESTON WAY
WEST CHESTER, PA. 19380
PHONE (215) 692-3030
TELEX 83-5348

7 January 1987

Mr. Thomas Pierson
Standard Chlorine of Delaware, Inc.
Governor Lea Boulevard
Delaware City, DE 19706

Dear Tom:

A short duration pumping test was run on Standard Chlorine's recovery well, RW-1, on 18 December 1986. Prior to the test the original pump had been removed for inspection by the contractor CZ Enterprises. CZ then rehabilitated the well in an attempt to increase the flow rate. The rehabilitation consisted of brushing the screened section of the well with a wire brush, to remove any incrustation, and redeveloping the gravel pack around the screen by forcing water into and out of the well by surging with a plunger-like surge block.

After rehabilitation, Standard Chlorine personnel installed an all-bronze submersible pump to test the well. Before the start of the test WESTON was informed by Standard Chlorine personnel that the pump discharge could not be directed to the waste impoundment near well RW-1. The discharge from the test pump was piped to the treatment system so no visual observation of the discharge was possible during the test. WESTON had also been informed that the flow meter on the discharge pipe was hooked up, but it became apparent during the pumping test that for some reason the flow meter was not in operation, so that the pumping rate, during the test, could not be determined.

At the start of the test the static, non-pumping, water level in RW-1 was 46.61 feet below the top of the well casing while in well RW-2, located approximately 270 feet east of RW-1, the static water level was 44.19 feet.

The pump was turned on at 2:02 pm, it took approximately 7 minutes for the water level to drop to a depth of 59.27 feet at which depth the pump began sucking air. This indicated that the test pump intake was located at approximately 59 feet below the top of the well. Although sucking air, the test pump still maintained a flow in the discharge line.

In order to maintain full flow in the line, the valve on the discharge line was adjusted so that the flow rate was reduced and the water level in the well rose above the pump intake.

The water level in RW-1 was maintained at a level between 56 and 58 feet below the top of the well casing for the remainder of the test, approximately one hour. Although the flow meter was not working during the test, a by-pass valve on the pump was momentarily opened and by visual observation it was estimated that the sustained flow from the pump was between 10 and 15 gpm.

During the test water level measurements in RW-2 indicated that the pumping effects of RW-1 caused a total drawdown of 0.52 feet in RW-2. This indicates that even at a reduced pumping rate, intercepting cones of drawdown can be achieved from the recovery wells.

After the test pump was shut off it took approximately 5 minutes for the water level in RW-1 to recover to within 98% of the original static level.

In summary, it appears that well RW-1 is capable of a sustained flow rate of 10-15 gpm. The sustained flow rate is limited by:

1. The amount of available drawdown, the static level was 46.61 feet, the total well depth is 63 feet, this means the water column in the well is approximately 16 feet high. Since the pump intake was approximately 4 feet off the bottom of the well there were only 12 feet of available drawdown during the test. It must be kept in mind that the well depths for the recovery wells was dictated by the depths at which the confining clay layer was encountered. The clay layer was not penetrated by the recovery wells to any significant extent in order to avoid breaching the confining layer and allowing contaminants to reach the lower water-bearing zone.

2. The natural sediments around the recovery wells are finer-grained than in the test wells constructed in the plant operations area. This fact, when coupled with the limited available drawdown, contributed to the lower flow rate.

From the pumping test it is apparent that the recovery well can perform their design function of intercepting contaminated ground water.

The optimum flow rate for continuous pumping appears to be in the range of 10 gpm.

Modifications to the existing recovery pumps were discussed with CZ Enterprises personnel. Although the pumping rates of the vertical turbines can be reduced to accommodate continuous pump, CZ Enterprises felt that the cost of the pump modifications and the additional power costs associated with running the modified pumps outweigh the cost of installing smaller pumps in the recovery wells. CZ Enterprises is preparing a cost proposal for the purchase and installation of all stainless steel pumps for use in the recovery wells. WESTON feels that the recovery wells can be pumped continuously, at a reduced rate and still perform their desired function. We will review CZ Enterprises proposal when it is received and will discuss the proposal and options with Standard Chlorine.

Very truly yours,

ROY F. WESTON, INC.

Abraham Thomas

Abraham Thomas, P.G.
Project Director
Geosciences Department

AT/rmk